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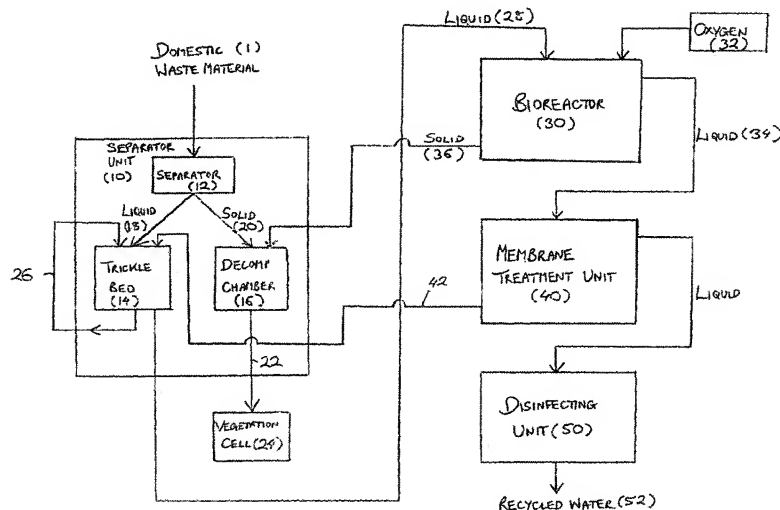
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(54) Title: APPARATUS AND METHOD FOR THE TREATMENT OF WASTE



(57) Abstract: A waste treatment system suitable for domestic use and capable of producing water suitable for recycling within the household. The system includes a bioreactor (30) and a decomposition chamber (16). The bioreactor (30) is adapted to digest liquid-base waste material using bacteria and is operable under anaerobic, anoxic and/or aerobic conditions. The decomposition chamber (16) decomposes substantially solid waste generated in the bioreactor. The bioreactor and decomposition chamber are in fluid communication such that substantially solid waste material generated in the bioreactor can be transferred to the decomposition chamber for further treatment. Resulting solids may optionally be forwarded to a vegetation cell (24) and the liquid (34) leaving the bioreactor may be optionally passed to a membrane treatment unit (40) and a disinfection unit (50).

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*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

## APPARATUS AND METHOD FOR THE TREATMENT OF WASTE

### **Field of the Invention**

This invention relates to a waste treatment system suitable for domestic use. It has  
5 been developed primarily as a system, which allows households to recycle sewage and other waste for domestic re-use.

### **Background of the Invention**

Any discussion of the prior art throughout the specification should in no way be  
10 considered as an admission that such prior art is widely known or forms part of common general knowledge in the field.

The management and treatment of domestic sewage and other waste is a growing problem facing cities and other populated areas. In highly populated areas, there is often a lack of appropriate sewage treatment facilities. If the sewage is not appropriately  
15 treated, it can contaminate water supplies and subsequently affect the health of inhabitants. There are an increasing number of areas where septic systems are causing problems with odour. Moreover, their impact on groundwater quality, and their use without some form of upgrade is being discouraged. In some areas, new septic systems are banned.

20 One approach to the problem has been the development of onsite treatment systems that either incorporate a septic system or use a similar anaerobic process as the first stage of the treatment system. They are often followed by a bioreactor/aeration system. Clarification follows either by settling, sand filtration, and in a few cases membrane filtration.

25 Many of these onsite treatment systems have relatively high operating costs, are often unreliable and require regular servicing. In the majority of systems there is a need to remove solids from the system and take away from the site on a regular basis (e.g. every 1-3 years depending on the load on the system). Government authorities are very concerned about the lack of management of these systems and, as a result, the discharge  
30 of water that does not meet the required standards.

In many countries the reuse of water is being encouraged. Many onsite systems produce water for surface irrigation of the required standard, but there are few domestic systems available that reliably produce water of a standard that can be recycled back to

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the home for non-potable use or have low enough nutrient levels to be disposed of on relatively small blocks of land.

WO02/089957 describes a treatment system for the treatment of primary waste on site. However, this treatment system alone does not produce water of high enough  
5 quality to be recycled back into the home for domestic use.

It would be desirable to provide a domestic waste treatment system, which produces water of high enough quality to be recycled back into the home for domestic use (*e.g.* non-potable use). It would be further desirable to provide a domestic waste treatment system, which is self-contained and which does not require regular human  
10 intervention to operate efficiently on a long-term basis.

It is an object of the present invention to overcome or ameliorate at least one of the disadvantages of the prior art, or to provide a useful alternative.

### Summary of the Invention

15 Accordingly, in a first aspect the present invention provides a waste treatment system suitable for domestic use comprising:

a bioreactor for digesting liquid-based waste material using bacteria, said bioreactor being operable under anaerobic, anoxic and/or aerobic conditions; and

a decomposition chamber for decomposing substantially solid waste material  
20 generated in the bioreactor;

wherein the bioreactor and the decomposition chamber are in fluid communication such that the substantially solid waste material generated in the bioreactor can be transferred to the decomposition chamber for further treatment.

Unless the context clearly requires otherwise, throughout the description and the  
25 claims, the words 'comprise', 'comprising', and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to".

As used herein, the term "liquid-based waste material" refers to any domestic waste material which is essentially a liquid. However, the term includes liquid waste  
30 materials containing solids, such as sewage. These waste materials are still liquid-based in the sense that the majority of the waste material is liquid with solids dispersed or distributed throughout the liquid.

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As used herein, the term “substantially solid waste” refers to a solid waste material, such as excess biosolids, generated in the bioreactor. This waste material will still contain some residual liquid and is a flowable material, in the sense that it may be pumped, siphoned or drained into the decomposition chamber. In the same sense, the  
5 term “fluid communication” means communication of flowable materials, which flowable materials, of course, include the substantially solid waste referred to above. Typically, fluid communication will be in the form of a hose, pipe or conduit.

The waste treatment system of the present invention is intended for “domestic use”. Domestic use may be the recycling of waste material (*e.g.* sewage) from a single  
10 household back to the same household. Thus, individual homes may install the waste treatment system of the present invention in a basement, outhouse, or other suitable area. However, domestic use may also include the relatively small scale treatment of waste material from a collection of households (*e.g.* up to 1000 households). Hence, the waste treatment system of the present invention may be used as a common treatment system  
15 for a collection of homes.

Moreover, whilst the waste treatment system of the present invention is suitable for domestic use, the invention is not in any way limited to this use. It will be appreciated that it would be equally suitable in some small- or medium-sized industries having an organic waste stream.

20 As is evident from the context, the term “transferred” means the transfer of material *via* the fluid communication *e.g.* by pumping, siphoning or even draining under gravity. For the avoidance of doubt, the term does not include transferring by manual intervention, such as scooping of solid waste and manually transferring.

The invention, in its preferred form, is advantageous because it provides a  
25 completely self-contained, simple system for handling and recycling household waste material, such as sewage, and provides a means for minimising and handling the biosolids formed. Previous attempts to solve the problem of recycling household waste suffered from an inability to cope with solid waste, either in the waste itself or generated in a bioreactor. Generally, the prior art systems separate solid waste generated in  
30 bioreactors by filtering or sieving (see, for example, US 5,725,770). This necessarily requires regular maintenance and human intervention. Regular human intervention in handling solid waste material is unpleasant and discourages the use of domestic waste treatment systems. The present invention, being compact, self-contained and requiring

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minimal handling of biosolids in its preferred form, is therefore a significant improvement over known waste treatment systems.

Preferably, the decomposition chamber is maintained under aerobic conditions. Aerobic conditions are preferably maintained by passive aeration of the decomposition chamber by means of one or more vents.

Preferably, the decomposition chamber comprises at least one mesh screen, more preferably a plurality of mesh screens arranged such that solid material passes through each mesh screen. There may be, for example, two, three or four mesh screens. Typically, the mesh screens are disposed substantially horizontally and stacked substantially vertically. Thus, the solid waste material will typically be treated on an uppermost mesh screen and, once treated, fall to the next mesh screen below and so on. A lower screen may be inclined to direct decomposed particulate solids towards a solids pump well.

Preferably, the mesh sizes of the mesh screens are graduated such that the solid waste material is treated on mesh screens of decreasing mesh size. For example, the decomposition chamber may have three mesh screens, an upper mesh formed from 25 mm woven mesh material, a middle mesh screen formed from 13 mm woven mesh material and a lower mesh formed from 5 mm woven mesh material. Other graduated mesh sizes may, of course, be used in the present invention.

Preferably, the decomposition chamber includes a population of worms and/or other suitable organisms for the decomposition of solid waste material. The worms and/or other organisms are preferably located on the mesh screens.

Preferably, the waste treatment system further comprises a vegetation cell for receiving solid material from the decomposition chamber. In its preferred form, the vegetation cell is placed underground (*e.g.* about 350 mm underground) in a trench and is aerated by means of a vent. A plant tube supporting a plant, such as a tree, may be disposed in the vegetation cell and separated from the vegetation cell by a porous medium. Nutrients and moisture from the vegetation cell may pass through into the plant tube *via* the porous medium. The plant tube may contain a suitable plant growing medium, such as potting mix or gravel. Hence, the vegetation cell may be used for supporting plant growth. One form of the vegetation cell used in the present invention is described in WO 02/89957.

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The decomposition chamber may receive some liquids as well as solids, in which case the liquids will pass straight through the decomposition chamber into the vegetation cell. Excessive amounts of liquid in the vegetation cell are generally undesirable.

Accordingly, the vegetation cell may be adapted to allow liquids to be pumped back to a  
5 trickle bed or the bioreactor. For example, liquids may be allowed to pass through the vegetation cell into a pumpwell, and then pumped back to a trickle bed or bioreactor.

A preferred form of the decomposition chamber used in the present invention is described in WO02/089957, which is incorporated herein by reference.

Turning now to the bioreactor this is preferably a Sequencing Batch Reactor  
10 (SBR) in a chamber for supporting bacteria under aerobic, anoxic and/or anaerobic conditions. The bacteria promote the digestion of a liquid-based waste material. The bioreactor will typically include a mechanical stirrer or agitator and may additionally include means for controlling temperature and pH. In its preferred form, the bioreactor is suitable for digesting the liquid-based waste material aerobically, anoxically and  
15 anaerobically. Hence, the bioreactor is preferably connected to an oxygen control system for controlling the concentration of oxygen in the bioreactor. The oxygen control system preferably comprises an oxygen source and a control valve, the control valve regulating the flow of oxygen reaching the bioreactor. When reference is made to oxygen herein, it is meant oxygen gas or any mixture of gases containing oxygen *e.g.* air. Preferably, the  
20 oxygen source is an air compressor, air blower and/or a venturi pump, which can suck air into the bioreactor.

As mentioned above, the liquid-based waste material processed in the bioreactor may include solids. Hence, the bioreactor may receive domestic waste, such as sewage, directly. Alternatively, the liquid-based waste material may be essentially liquid, the  
25 liquid-based waste material having first been processed by a separator unit before reaching the bioreactor. Combinations of these two alternatives are also envisaged in the present invention.

In a particularly preferred form of the present invention, the waste treatment system further comprises a separator unit for separating liquid and solid waste, the  
30 separator unit and bioreactor being in fluid communication such that liquid exiting the separator unit enters the bioreactor. Hence, the bioreactor is "downstream" of the separator unit.

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Preferably, the separator unit includes the decomposition chamber described above. More preferably, the decomposition chamber treats solids separated from liquids in the separator unit in addition to the substantially solid waste material generated in the bioreactor. Generally, domestic waste enters the separator unit where it is separated into  
5 essentially solid and liquid waste. The solid waste is preferably processed in the decomposition chamber described above and, after processing, transferred to the vegetation cell described above.

Preferably, the separator unit also includes a trickle bed for treating liquid waste separated from solid waste in the separator unit. Typically, the trickle bed comprises a  
10 plurality of layers with alternating relatively coarse and relatively fine trickle bed media. Preferably, the trickle bed is maintained under essentially aerobic conditions for supporting aerobic bacteria. This may be achieved simply by having one or more vents in the separator unit.

Preferably, the trickle bed and the decomposition chamber are separated by a  
15 porous barrier which allows worms and other organisms to pass between the two (that is, the trickle bed and the decomposition chamber), but which prevents mixing of separated liquids and solids. Preferably, the trickle bed is formed in an annular space defined by the decomposition chamber, positioned centrally, and the external walls of the separator unit.

20 Liquid separated from solids in domestic waste typically passes through the trickle bed where it is digested, at least partially, by bacteria under aerobic conditions. Preferably, the trickle bed comprises a recirculation loop, such that liquid exiting the trickle bed may optionally be recycled back through the trickle bed for further treatment. Preferably, the separator unit also comprises a trickle bed control system for allowing  
25 the degree of treatment in the trickle bed to be controlled. For example, the trickle bed control system may be used to control the number of recycles through the trickle bed, thereby controlling the extent of digestion. In some circumstances, a relatively limited degree of digestion may be favourable, because liquids receiving limited treatment in the trickle bed are rich in carbon and may be used to optimise nitrification (conversion of  
30 ammonia to nitrate) and/or denitrification (conversion of nitrate to nitrogen) in the bioreactor.

Preferably, the recirculation loop includes an in-line venturi pump, wherein materials are transferable between treatment units in the waste treatment system by



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means of the venturi pump. Preferably, liquid is recirculated through the trickle bed by an electric pump. Preferably, the venturi pump creates a vacuum, which can be used to siphon materials between treatment units in the waste treatment system. The siphoning action is preferably controlled by a system of valves. The valves are preferably  
5 automatically operable and controlled by a central control system.

In an alternative arrangement, the separator unit does not comprise a trickle bed, such that liquid separated in the separator unit passes directly to the bioreactor.

The separator itself may be of any convenient design. However, a particularly preferred form of the separator is a geometric shape (*e.g.* a cone) that allows  
10 substantially all solid waste to fall off an outer surface and the majority of the liquid waste to flow on the surface and into, for example, a liquid collection means.

A particularly preferred form of the separator unit described above (including all the features of decomposition chamber, trickle bed, separator *etc.*) is described in WO02/089957, which is incorporated herein by reference.

15 In a preferred form of the present invention, the waste treatment system further comprises a membrane treatment unit in fluid communication with the bioreactor for treating liquid exiting the bioreactor. Hence, the membrane treatment unit is “downstream” of the bioreactor. The purpose of the membrane treatment unit is to remove any remaining solid particles, including pathogens, from the liquid.

20 The membrane treatment unit preferably comprises a membrane filter for separating fine particulate solids from liquid in the membrane treatment unit. The membrane filter may also remove some Faecal Coliforms, parasites and viruses from the liquid. Preferably, the membrane filter comprises synthetic microporous membranes in the form of hollow fibres bundles, tubular cartridges or flat sheet cartridges. The  
25 membranes may be microfilters or ultrafilters, as known by those skilled in the art, and are typically polymeric (*e.g.* polysulfones). The membrane treatment unit may include systems for automatically periodically cleaning the membrane filter. For example, a high pressure (100 kPa) backwash at predetermined intervals may be used to prevent clogging of the membrane filter. It is preferred that the concentration of dissolved oxygen in the  
30 membrane treatment unit is maintained in excess of about 2 mg/l to enhance filtration and to ensure that solid phosphates do not redissolve into the liquid.

In a particularly preferred form, the membrane treatment unit is in fluid communication with the trickle bed, the bioreactor or the decomposition chamber such

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that fine particulate solids captured in the membrane treatment unit can be transferred, usually as a liquid dispersion, to the trickle bed, bioreactor or decomposition chamber for further treatment. If necessary, the captured solids are mixed with sufficient quantity of water to facilitate their transferral to the trickle bed or bioreactor. Alternatively, the captured solids may be transferred to the decomposition chamber, depending on the quantity of liquid contained therein. Generally, it is preferred not to transfer excessive quantities of liquid to the decomposition chamber.

In another preferred form of the present invention, the waste treatment system further comprises a disinfecting unit in fluid communication with the membrane treatment unit for substantially disinfecting liquid exiting the membrane treatment unit. Hence the disinfecting unit is "downstream" of the membrane treatment unit.

The disinfecting unit preferably comprises a UV and/or ozone treatment zone, which kills or inactivates any remaining Faecal Coliforms, parasites or viruses in the liquid. If the liquid (now "water") is to be stored for more than about a day, it is preferred that chlorine is also added in a chlorine treatment zone. The chlorine is maintained in the water at residual levels and provides a lasting disinfecting effect.

The waste treatment system described above is preferably fully automated and controlled by a central control system. Suitable sensors or probes may be used to monitor conditions in the separator unit, the bioreactor, the membrane treatment unit and/or the disinfecting unit. This information may then be fed back to a central computer, which automatically adjusts operational parameters to optimise the treatment of waste water. The condition of liquid in the bioreactor is particularly important and the central computer may be used to control the carbon content of liquid feed, the sequencing of the SBR process, temperature, pH, oxygen levels *etc.* With a suitable central control system, the waste treatment may be left to run relatively unattended and without human intervention.

In a second aspect the present invention provides a waste treatment system suitable for domestic use comprising:

- a bioreactor for digesting liquid-based waste material using bacteria, said bioreactor being operable under anaerobic, anoxic and/or aerobic conditions; and
- a trickle bed in fluid communication with the bioreactor, said trickle bed providing a liquid feed for the bioreactor;

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wherein the degree of treatment in the trickle bed is adjustable such that digestion conditions in the bioreactor may be optimised.

In general, all preferred features of the first aspect of the present invention may be preferred features of the second aspect of the invention. In particular, the trickle bed  
5 preferably includes a recirculation system. Preferably, the degree of treatment in the trickle bed is determined by the number of recirculations through the trickle bed.

Preferably, the degree of treatment in the trickle bed is adjustable to provide an optimum level of carbon for nitrification and/or denitrification processes in the bioreactor. Hence, some relatively untreated liquid, having a high carbon content, may  
10 be periodically injected into the bioreactor to optimise denitrification.

In a third aspect, the present invention provides a waste treatment system suitable for domestic use comprising:

a treatment unit including a recirculation loop for recirculation of a liquid through said treatment unit; and  
15 a venturi pump in line with said recirculation loop;  
wherein materials are transferable between treatment units in the waste treatment system by means of said venturi pump.

Preferably, the treatment unit including a recirculation loop is a trickle bed. Preferably, liquid is recirculated through the trickle bed by an electric pump. Preferably,  
20 the venturi pump creates a vacuum, which can be used to transfer materials between treatment units in the waste treatment system, such as by siphoning or direct suction. For example, liquid may be siphoned from the trickle bed to the bioreactor; substantially solid waste material may be siphoned from the bioreactor to the decomposition chamber; liquid may be siphoned from the bioreactor to the membrane treatment unit; captured  
25 fine particulate solids in the membrane treatment unit may be siphoned (together with some liquid, if required) to the trickle bed, the bioreactor or the decomposition chamber; liquid from the membrane treatment unit may be siphoned to the disinfecting unit *etc.*

The siphoning action is preferably controlled by a system of valves. The valves are preferably automatically operable and controlled by a central control system.

30 Alternatively, the venturi may transfer material (*e.g.* captured fine particulate solids from the membrane treatment unit) to the trickle bed recirculation loop by direct suction.

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In general, all preferred features of the first and second aspects of the present invention may be preferred features of the third aspect of the present invention.

In a fourth aspect, the present invention provides a process for treating waste material comprising the steps of:

- 5 (a) providing a bioreactor for digesting liquid-based waste material using bacteria, said bioreactor being operable under anaerobic, anoxic and/or aerobic conditions;
- (b) providing a decomposition chamber for decomposing substantially solid waste material, wherein the bioreactor and the decomposition chamber are in fluid  
10 communication;
- (c) adding a liquid-based waste material to the bioreactor;
- (d) digesting the liquid-based waste material in the bioreactor, thereby generating a liquid and a substantially solid waste material; and
- (e) transferring said substantially solid waste material to said decomposition  
15 chamber.

The process of the present invention is preferably conducted using a waste treatment system as described above. Hence, the decomposition chamber and the bioreactor are preferably both of the form described above.

- 20 Preferably, step (c) includes mixing the liquid-based waste material with any material in the bioreactor remaining from a previous cycle of the waste treatment. This maximises efficiency and minimises the build up of permanent solids deposits in the bioreactor, which cannot be transferred to the decomposition chamber.

- 25 Preferably, step (d) includes digestion under conditions in which aerobic, anoxic and anaerobic zones can occur. Hence, this digestion is preferably conducted in a variable oxygenated environment, such that the concentration of dissolved oxygen is between 0.05 and 2.0 mg/l, more preferably between 0.1 and 1.5 mg/l, more preferably between 0.2 and 0.8 mg/l.

- 30 Preferably, step (d) also includes an aerobic digestion step. The aerobic digestion step is preferably conducted in an oxygenated atmosphere, such that the concentration of dissolved oxygen is greater than about 2.0 mg/l. A dissolved oxygen concentration of greater than about 2.0 mg/l ensures that the majority of solid phosphates do not redissolve into liquid in the bioreactor. Moreover, the use of two types of digestion steps is advantageous, because this maximises the degree of digestion in the bioreactor.

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Preferably, step (e) includes a settling step in which solid waste material is allowed to settle out, and a decanting step in which supernatant liquid is removed from the bioreactor. Decanting supernatant liquid will generally be carried out before transferral of solid waste material to the decomposition chamber. This avoids transferring excessive amounts of liquid to the decomposition chamber.

In a particularly preferred form, the present invention provides a waste treatment process comprising the steps of:

- (a) providing a bioreactor for digesting liquid-based waste material using bacteria, said bioreactor being operable under anaerobic, anoxic and/or aerobic conditions;
- (b) providing a decomposition chamber for decomposing substantially solid waste material, wherein the bioreactor and the decomposition chamber are in fluid communication;
  - (c1) adding a liquid-based waste material to the bioreactor;
  - (c2) mixing the liquid-based waste material with any material in the bioreactor remaining from a previous waste treatment cycle;
  - (d1) digesting the liquid-based waste material in an oxygenated atmosphere, such that the concentration of dissolved oxygen is between 0.05 and 2.0 mg/l.
  - (d2) further digesting in an oxygenated atmosphere, such that the concentration of dissolved oxygen is greater than 2.0 mg/l;
  - (e1) allowing substantially solid waste material generated in steps (d1) and (d2) to settle;
  - (e2) decanting supernatant liquid; and
  - (e3) transferring the substantially solid waste material to the decomposition chamber for further treatment.

The stages in this process are preferably automated and controlled by a computer programmed with appropriate software. The length of the digestion steps (d1) and (d2) may be varied depending on the type of waste and the degree of waste treatment required. If, for example, a high BOD load is anticipated (*e.g.* parties, extra visitors *etc.*), then this information may be programmed into a control computer and the residence time in the bioreactor during the digestion steps changed accordingly.

As mentioned above, the liquid-based material may include some solids or it may be essentially a liquid exiting a separator unit. Thus, in a particularly preferred form, the

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process of the present invention further comprises the step of providing a separator unit, which may be of the form described above and/or described in WO02/089957.

In this preferred embodiment which includes providing a separator unit, the degree of treatment in the trickle bed is preferably controlled in order to optimise digestion  
5 conditions in the bioreactor. For example, suitable probes may be included in the bioreactor which monitor the conditions therein (*e.g.* concentration of dissolved oxygen, oxygen reduction potential *etc.*). This information may then be used to control the degree of treatment in the trickle bed and optimise conditions in the bioreactor.

Preferably, in the process of the present invention, liquid exiting the separator unit  
10 is periodically relatively untreated. This relatively untreated liquid may be used as an additional carbon source for optimising nitrification and/or denitrification in the bioreactor.

Preferably, the process of the present invention further comprises the steps of:

(f) providing a membrane treatment unit in fluid communication with the  
15 bioreactor; and

(g) passing liquid from the bioreactor through the membrane treatment unit, thereby separating fine particulate solids from the liquid.

The membrane treatment unit is preferably of the type described above. In a particularly preferred form, the process comprises the further step of:

20 (h) transferring the fine particulate solids captured in the membrane treatment unit, optionally mixed with water, to the trickle bed, bioreactor or decomposition chamber.

Since the quantity of fine particulate solids generated in the membrane treatment unit is small, they are usually transferred (along with a suitable amount of water) back to  
25 the trickle bed or bioreactor. However, the transfer of these fine particulate solids to the decomposition chamber is also contemplated within the scope of this invention.

Preferably, the process of the present invention further comprises the steps of:

(i) providing a disinfecting unit in fluid communication with the membrane treatment unit; and

30 (j) passing liquid from the membrane treatment unit through the disinfecting unit, thereby providing recycled water for domestic use.

The disinfecting unit is preferably of the type described above.

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In a fifth aspect, the present invention provides a method of controlling digestion conditions in a bioreactor comprising: providing a trickle bed in fluid communication with said bioreactor, said trickle bed providing a liquid feed for said bioreactor, and adjusting the degree of treatment in the trickle bed such that digestion conditions in the bioreactor are optimised. Preferably, the degree of treatment in the trickle bed is adjusted to provide an optimum level of carbon for nitrification and/or denitrification processes in the bioreactor.

In a sixth aspect, the present invention provides a method of transferring materials between treatment units in a waste treatment system, comprising: providing a venturi pump in line with a recirculation loop in one treatment unit, and using said venturi pump to transfer materials between treatment units. Preferably, the treatment unit having a recirculation loop is a trickle bed.

#### **Brief Description of the Drawings**

A preferred embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 shows a simplified schematic view of a waste treatment system according to the present invention.

Figure 2 shows a simplified schematic view of a venturi pump system according to the present invention.

#### **Description of a Preferred Embodiment**

Referring to Figure 1, there is shown a waste treatment system having a separator unit 10, a bioreactor 30, a membrane treatment unit 40 and a disinfecting unit 50.

Domestic waste material 1 enters the separator unit 10. The separator unit comprises a separator 12, trickle bed 14 and decomposition chamber 16.

The waste material 1 enters the separator 12 and is divided into liquid stream 18 and solid stream 20.

The solids 20 are fed into the decomposition chamber 16 where they decompose under natural aerobic processes, for example, on a series of mesh screens. A combination of living organisms on the mesh screens aid these decomposition processes. Solids which have broken down in the decomposition chamber 16 slowly fall to the bottom of the chamber through decreasing sized mesh screens. The mesh screens are

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configured to prevent untreated solids from moving directly to the bottom of the decomposition chamber 16. The treated solids 22 from the decomposition chamber are then pumped to the vegetation cell 24 with a small quantity of water.

The liquid stream 18 separated from the solids 20 enters an aerobic trickle bed 14.  
5 The liquid exiting the trickle bed may be recirculated back through the trickle bed via recirculation line 26, for further treatment. The degree of treatment in the trickle bed is controlled by a trickle bed 14 control system (not shown).

At predetermined times ranging from 4 to 8 hours, liquid is pumped from the separator unit 10 via line 28 to fill the bioreactor 30. In the bioreactor 30, a sequence of  
10 operations is carried out as follows:

*(1) Fill*

The bioreactor 30 is filled with liquid 28 from the separator unit 10.

*(2) Mix*

Incoming material is mixed with material retained in the bioreactor 30 after the  
15 previous cycle using a mixer.

*(3) Low Oxygen Aeration*

In the first aeration sequence, liquid is aerated from a compressor/oxygen source 32 via a control valve. Low levels of oxygen are maintained to promote anaerobic, anoxic and aerobic conditions in such a way that bacteria reduce BOD, phosphate and  
20 nitrogen. The oxygen levels are measured using an ORP (Oxygen Reduction Potential) probe and maintained between 0.2 and 0.8 mg/l by a suitable oxygen control system. Measurements from the probe are used to determine the efficacy of digestion in the bioreactor. The composition of feed liquid 28 into the bioreactor 30 may be adjusted to optimise conditions in the bioreactor 30, using the trickle bed control system e.g.  
25 additional carbon may be fed into the bioreactor by lowering the number of recycles in the trickle bed.

*(4) High Oxygen Aeration*

In the second aeration, the level of dissolved oxygen is set to exceed 2 mg/l. This ensures that the maximum amount of phosphate is retained in the solids.

30 *(5) Settle*

On completion of aeration, the material is allowed to settle in the bioreactor 30.

*(6) Decant*



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After settling, a supernatant liquid 34 is drained from the top part (e.g. top 40%) of the bioreactor 30 to the membrane treatment unit 40.

*(7) Solids Siphoned*

At least part of the solids 36 remaining are then siphoned via line 36 from the bioreactor back to the decomposition chamber. A series of valve systems is used to control the liquid draining 34 and solid siphoning 36 steps.

Supernatant liquid 36 from step (6) above is transferred to the membrane treatment unit. This liquid is drawn through the membranes under 20 kPa vacuum into a treated water tank using a venturi. The membranes are regularly backwashed e.g. for 1 min at 100 kPa to optimise flow through the membranes. During backwash, air may be added to the base of the membrane to aid removal of solids and biofilm from the membrane surface. The membranes used are preferably ultrafiltration hollow fibres (polysulfone, nominal molecular weight cut off at 50 kD). Air is also programmed to be added for short periods to ensure liquid in the membrane treatment unit contains in excess of 2 mg/l of dissolved oxygen.

Apart from removing solids, the membranes provide a barrier for removing Faecal Coliforms, Cryptosporidium (typically 4-6 microns in diameter) and Giardia cysts (typically 12-20 microns in diameter), as well as other parasites and viruses.

A small quantity of solids 42 is removed from the bottom membrane unit on a regular basis. These solids, accompanied by some liquid, are siphoned back to the trickle bed 14.

After the treated water has passed through the membrane treatment unit, it may require or be desirable to undergo further disinfection to kill or inactivate any remaining Faecal Coliforms, parasites or viruses to provide suitable water 52 for recycling. This is carried out in a disinfecting unit 50 using UV or ozone, and in cases where storage is required for more than 24 hours, chlorine is added to maintain a residual level of disinfectant in the recycled water.

The waste treatment system has a central control system to control process parameters, enable the system to cope with varying load, control a membrane integrity test and monitor systems operation. Several signals will be regularly sent to a remote monitoring site, one indicating whether the system is operating satisfactorily or if there is a problem that needs attention immediately, and one providing information regarding general operating parameters.

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It will be seen that the present invention provides a compact, self-contained waste treatment system suitable for domestic use, which requires little or no human intervention. The resultant recycled water will typically have the following quality parameters:

5	BOD	< 10 mg/l
	SS	< 5 mg/l
	Total P	< 10 mg/l
	Total N	< 10 mg/l
	Turbidity	< 1 NTU
10	Faecal Coliforms	< 10 CFU
	Cysts and other parasites	Not detectable
	Viruses	< 0.001%

Referring to Figure 2, there is shown a trickle bed having a liquid recirculation loop 26. A venturi pump 61 is in line with the recirculation loop 26. Liquid is recirculated and feeds through the venturi pump 61 by means of an electric pump 62. As liquid recirculates via the venturi pump 61, a vacuum is generated by the venturi action. This vacuum is used to control the transfer of materials throughout the waste treatment system by a siphoning action. Valves 63, 64, 65 and 66 are opened and closed in a predetermined sequence to create a siphon in a particular transfer conduit between two preselected treatment units. The venturi pump 61 in combination with the valves obviates the need for multiple electric pumps to effect individual transfer operations in the waste treatment system. However, some transfers throughout the waste treatment system may still be performed, or assisted by, electric pumps.

The skilled person will, of course, appreciate that the present invention has been described by way of example only and may be embodied in many other forms within the scope of the invention.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:-

1. A waste treatment system suitable for domestic use comprising:  
a bioreactor for digesting liquid-based waste material using bacteria, said  
5 bioreactor being operable under anaerobic, anoxic and/or aerobic conditions; and  
a decomposition chamber for decomposing substantially solid waste material  
generated in the bioreactor;  
wherein the bioreactor and the decomposition chamber are in fluid communication such  
that the substantially solid waste material generated in the bioreactor can be transferred  
10 to the decomposition chamber for further treatment.
2. The waste treatment system of claim 1, wherein the decomposition chamber  
comprises a plurality of mesh screens arranged such that solid material passes through  
each mesh screen.  
15
3. The waste treatment system claim 2, wherein the mesh screens support worms  
and/or other organisms for the decomposition of substantially solid waste material.
4. The waste treatment system of any one of the preceding claims further comprising  
20 a vegetation cell for receiving material from the decomposition chamber.
5. The waste treatment system of any one of the preceding claims, wherein the  
bioreactor is connected to an oxygen control system for controlling the concentration of  
oxygen in the bioreactor.  
25
6. The waste treatment system of any one of the preceding claims further comprising  
a separator unit for separating liquid and solid waste, said separator unit and bioreactor  
being in fluid communication such that liquid exiting the separator unit enters the  
bioreactor.  
30
7. The waste treatment system of any one of the preceding claims, wherein the  
decomposition chamber of any one of claims 1 to 3 is included in the separator unit.
8. The waste treatment system of claim 6 or claim 7, wherein the separator unit  
35 includes a trickle bed for treating liquid waste separated from solid waste in the  
separator unit.

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9. The waste treatment system of claim 8 further comprising a recirculation loop, such that liquid exiting the trickle bed may be optionally recycled back through the trickle bed for further treatment.

5

10. The waste treatment system claim 8 or 9 further comprising a trickle bed control system for allowing the degree of treatment in the trickle bed to be controlled.

11. The waste treatment system of claim 9 or 10, wherein the recirculation loop  
10 includes an in-line venturi pump, wherein materials are transferable between treatment units in the waste treatment system by means of said venturi pump.

12. The waste treatment system of any one of the preceding claims further comprising a membrane treatment unit in fluid communication with the bioreactor for treating liquid  
15 exiting the bioreactor.

13. The waste treatment system of any one of claim 12, wherein the membrane treatment unit is in fluid communication with the bioreactor, trickle bed or decomposition chamber such that fine particulate solids captured in the membrane  
20 treatment unit can be transferred to the bioreactor, trickle bed or decomposition chamber for further treatment.

14. The waste treatment system of any one of the preceding claims further comprising a disinfecting unit in fluid communication with the membrane treatment unit for  
25 substantially disinfecting liquid exiting the membrane treatment unit.

15. A waste treatment system suitable for domestic use comprising:  
a bioreactor for digesting liquid-based waste material using bacteria, said bioreactor being operable under anaerobic, anoxic and/or aerobic conditions; and  
30 a trickle bed in fluid communication with said bioreactor, said trickle bed providing a liquid feed for said bioreactor;  
wherein the degree of treatment in the trickle bed is adjustable such that digestion conditions in the bioreactor may be optimised.

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16. The waste treatment system of claim 15, wherein the degree of treatment in the trickle bed is adjustable to provide an optimum level of carbon for nitrification and/or denitrification processes in the bioreactor.

- 5 17. A waste treatment system suitable for domestic use comprising:  
a treatment unit including a recirculation loop for recirculation of a liquid  
through said treatment unit; and  
a venturi pump in line with said recirculation loop;  
wherein materials are transferable between treatment units in the waste treatment system  
10 by means of said venturi pump.

18. The waste treatment system of claim 17, wherein the treatment unit including a recirculation loop is a trickle bed.

- 15 19. A process for treating waste material comprising the steps of:  
(a) providing a bioreactor for digesting liquid-based waste material using  
bacteria, said bioreactor being operable under anaerobic, anoxic and/or aerobic  
conditions;  
(b) providing a decomposition chamber for decomposing substantially solid  
20 waste material, wherein the bioreactor and the decomposition chamber are in fluid  
communication;  
(c) adding a liquid-based waste material to the bioreactor;  
(d) digesting the liquid-based waste material in the bioreactor, thereby generating  
a liquid and a substantially solid waste material; and  
25 (e) transferring said substantially solid waste material to said decomposition  
chamber.

20. The process of claim 19 comprising the steps of:  
(a) providing a bioreactor for digesting liquid-based waste material using  
30 bacteria, said bioreactor being operable under anaerobic, anoxic and/or aerobic  
conditions;  
(b) providing a decomposition chamber for decomposing substantially solid  
waste material, wherein the bioreactor and the decomposition chamber are in fluid  
communication;

- 20 -

- (c1) adding a liquid-based waste material to the bioreactor;
  - (c2) mixing the liquid-based waste material with any material in the bioreactor remaining from a previous waste treatment cycle;
  - (d1) digesting the liquid-based waste material in an oxygenated atmosphere, such  
5 that the concentration of dissolved oxygen is between 0.05 and 2.0 mg/l.
  - (d2) further digesting in an oxygenated atmosphere, such that the concentration of dissolved oxygen is greater than 2.0 mg/l;
  - (e1) allowing substantially solid waste material generated in steps (d1) and (d2) to settle;
  - 10 (e2) decanting supernatant liquid; and
  - (e3) transferring the substantially solid waste material to the decomposition chamber for further treatment.
21. The process of any one of claim 19 or 20, wherein there is further provided a  
15 separator unit as defined in any one of claims 6 to 11.
22. The process of claim 21, wherein the degree of treatment in the trickle bed is controlled in order to optimise digestion conditions in the bioreactor.
- 20 23. The process of claim 22, wherein the liquid exiting the separator unit is periodically relatively untreated.
24. The process of claim 23, wherein the periodically relatively untreated liquid is used as an additional carbon source for optimising nitrification and/or denitrification in  
25 the bioreactor.
25. The process of any one of claims 19 to 24 further comprising the steps of:
- (f) providing a membrane treatment unit in fluid communication with the bioreactor; and
  - 30 (g) passing liquid from the bioreactor through the membrane treatment unit, thereby separating fine particulate solids from the liquid.
26. The process any one of claim 25 further comprising the step of:

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(h) transferring the fine particulate solids captured in the membrane treatment unit, optionally mixed with water, to the trickle bed, bioreactor or decomposition chamber.

5 27. The process of claim 25 or 26, further comprising the steps of:

(i) providing a disinfecting unit in fluid communication with the membrane treatment unit; and

(j) passing treated liquid from the membrane treatment unit through the disinfecting unit, thereby providing recycled water for domestic use.

10

28. A method of controlling digestion conditions in a bioreactor comprising providing a trickle bed in fluid communication with said bioreactor, said trickle bed providing a liquid feed for said bioreactor, and adjusting the degree of treatment in the trickle bed such that digestion conditions in the bioreactor are optimised.

15

29. The process of claim 28, wherein the degree of treatment in the trickle bed is adjusted to provide an optimum level of carbon for nitrification and/or denitrification processes in the bioreactor.

20 30. A method of transferring materials between treatment units in a waste treatment system, comprising providing a venturi pump in line with a recirculation loop in one treatment unit, and using said venturi pump to transfer materials between treatment units.

25 31. The method of claim 30, wherein said treatment unit having a recirculation loop is a trickle bed.

1/2

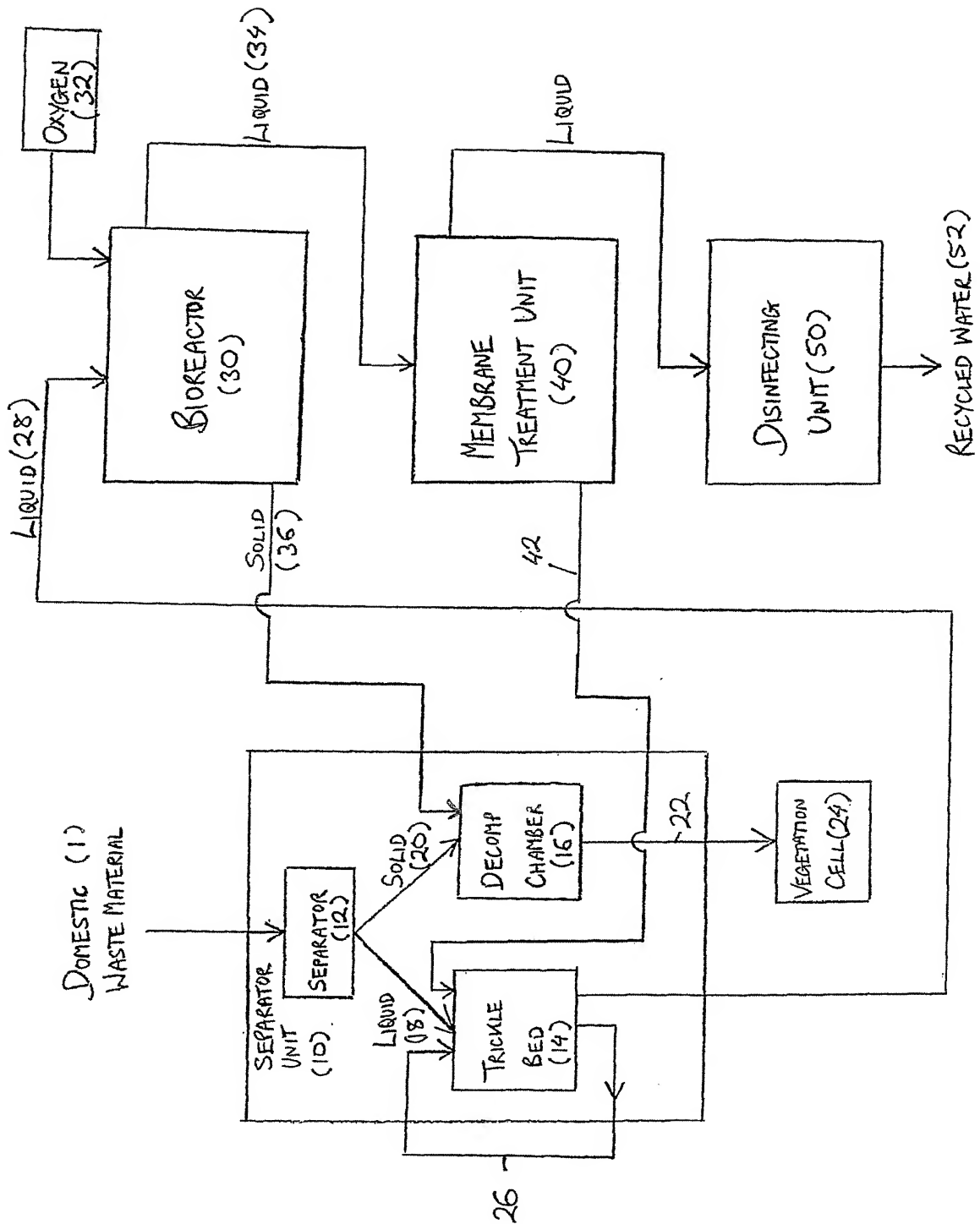
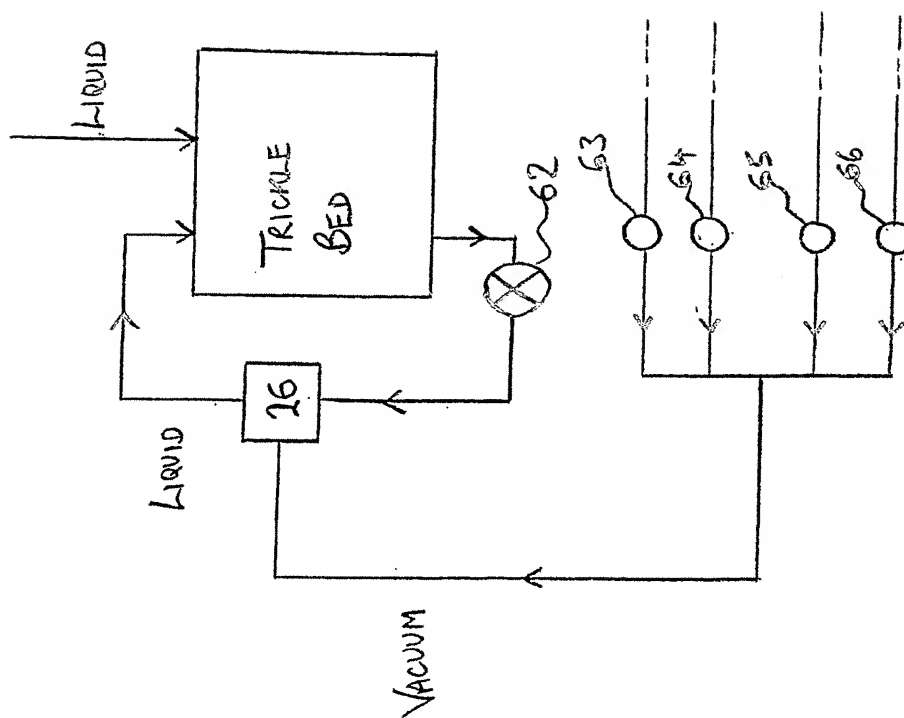


FIGURE 1



FIGURE 2

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/AU2004/000513

## A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. <sup>7</sup>: C02F 9/14, C02F 9/02, C02F 3/04, C02F 3/28

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C02F 9/00, 9/02, 9/14, 3/00, 3/02, 3/04, 3/28

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

DWPI + KW(WORM+ and VERMI+)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO,A,200246127 (GILCHRIST et al)13 June 2002 See whole document	1-4,19
X	WO,A,200190006 (GRAY et al) 29 November 2001 See whole document	15-18, 30-31
X	WO,A,200066501 (CARROLL) 9 November 2000 See whole document	17-18,30-31
X	GB,A,2077712 (SOCIETE SAPS ANTICORROSION) 23 December 1981 See whole document	17-18,30-31

☒ Further documents are listed in the continuation of Box C

☒ See patent family annex

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 5 July 2004	Date of mailing of the international search report 22 JUL 2004
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustalia.gov.au Facsimile No. (02) 6285 3929	Authorized officer  M.R. OLLEY Telephone No : (02) 6283 2143

# INTERNATIONAL SEARCH REPORT

International application No.  
**PCT/AU2004/000513**

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO,A,199901385 (URRIOLA) 14 January 1999 See whole document	
A	AU,B,722651 (WISEMAN) 6 November 1998 See whole document	

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/AU2004/000513

### Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

### Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:  
See Supplemental Sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.  
☐ No protest accompanied the payment of additional search fees.

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2004/000513

### Supplemental Box

(To be used when the space in any of Boxes I to VIII is not sufficient)

#### Continuation of Box No: III

The claims do not relate to one invention only (or to a group of inventions so linked as to form a single general inventive concept). In assessing whether there is more than one invention claimed, I have given consideration to those features which can be considered to be "special technical features". These are features that potentially distinguish the claimed combination of features from the prior art. Where different claims have different special technical features they define different inventions. I have found claims having different special technical features as follows:

- (1) Claims 1-14 and 19-27. It is considered that a decomposition chamber for decomposing substantially solid waste material generated in the bioreactor comprises a first special technical feature.
- (2) Claims 15-16 and 28-29. It is considered that a trickle bed in fluid communication with said bioreactor, said trickle bed providing a liquid feed for said bioreactor comprises a second special technical feature.
- (3) Claims 17-18 and 30-31. It is considered that a treatment unit including a venturi pump in a recirculation loop for recirculation of a liquid through said treatment unit comprises a third technical feature.

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/AU2004/000513

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member			
WO	0246127	AU	22137/02		
WO	0190006	AU	65081/01	US	2001045392
WO	0066501	AU	46881/00	US	6238563
GB	2077712	BE	889185	CA	1170378
		DE	3122389	FR	2484447
CH	647546				
WO	9901385	AU	82003/98	EP	1017638
AU	722651	AU	45132/97		
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.					
END OF ANNEX					

